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Allocation and management of water for maintaining wetland ecosystem functions: processes, strategies and tools

Note: This paper provides background information, with a focus on processes, strategies and tools, in support of draft resolution COP8 – DR 1, the Annex to which provides guidelines for Contracting Parties on water allocations and management for maintaining ecosystem functions.

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1. Introduction

1. This paper provides information and case studies on different aspects of the process of determining appropriate allocations of water to maintain the functioning of wetlands, so that they can continue to provide their many goods and services, including maintenance of their biological diversity, to people.

2. The paper first outlines the importance of wetland functions and their role in the hydrological cycle, as well as the basis of sustainable management of water and wetlands. It then describes various decision-making processes for determining water allocations and the scientific and technical tools for use in applying methodologies for water allocation. Finally it describes implementation options and management tools for achieving appropriate allocations in order to maintain wetland ecosystem functions.

3. Wetland ecosystems are adapted to the prevailing hydrological regime. The spatial and temporal variation in water depth, flow patterns and water quality, as well as the frequency and duration of inundation, are often the most important factors determining the ecological character of a wetland. Coastal and marine wetlands are often highly dependent on inputs of freshwater and associated nutrients and sediments from rivers.

4. Impacts on wetlands can be caused by both human activities within them and, because of the interconnectedness of the hydrological cycle, by activities that take place within the wider catchment. Human modification of the hydrological regime, by removing water (including groundwater) or altering fluxes, can have major detrimental consequences for the integrity of wetland ecosystems. Insufficient water reaching wetlands, due to abstractions, storage and diversion of water for public supply, agriculture, industry and hydropower, is a major cause of wetland loss and degradation. A key requirement for wetland conservation and wise use is to ensure that adequate water of the right quality is allocated to wetlands at the right time.

5. Many river basin authorities and water agencies have insufficient appreciation of the socio-economic values and benefits provided by wetlands in terms of their role in maintaining the hydrological cycle, their productivity (e.g., fisheries and livestock grazing), and their social importance (e.g., cultural heritage). More crucially, many perceive wetlands only as competing users of water, with high evaporative demand, rather than an essential component of sustainable water management.

6. The allocation of water resources is an important and increasing challenge for society. The particular challenge is to decide how much water, and of what quality, should be reserved for the maintenance of ecosystems through an "environmental flow allocation", so as to maintain their provision of their range of valuable natural goods and services, and how much water can be allocated for agriculture, industry, and domestic services.

7. To help make this decision, it is essential that the costs and benefits of maintaining ecosystems and their functions be quantified and compared to the costs and benefits of other offstream or indirect uses of water.

2. Wetland ecosystems and their functions in the context of water resources management

8. Ecosystem functions are defined as "the capacity of natural processes and components of natural or semi-natural systems to provide goods and services that satisfy human needs." These are generally grouped into four types of functions:

   i) regulation;
   ii) provision of transport and tourism opportunities;
   iii) production; and
   iv) the provision of habitats and cultural attributes[4].

9. These functions as they relate to wetland ecosystems are summarised below. Since the water allocated for the management of wetland ecosystems is usually intended to maintain or enhance ecosystem functions for the benefit of people, determining which wetland ecosystem functions can and should be maintained in a catchment will determine the nature and extent of the water allocation which is made. For further information on wetland values and functions, see Ramsar's *Wetland Values and Functions* factsheets (Ramsar Bureau 2001).

2.1 Regulation

10. Wetlands are important regulators of water quantity and water quality. Several types of wetlands are known to act as hydrological buffers, reducing peak flood flows and volumes through retention of water in surface and groundwater storage, and reducing the risks of flood damage downstream. Maintenance of natural hydrological buffering capacity also provides for greater reliability of instream flows during dry periods – this can be extremely important for people who are reliant on subsistence irrigation farming.

11. Wetland ecosystems are able to assimilate some biodegradable waste products, providing important treatment capabilities for substances such as excess nutrients and sediments, and improving water quality for downstream users. Some wetlands trap toxic pollutants such as heavy metals, which can later be removed for safe disposal, if necessary. The value of these services may be considerable, since technical means of regulating water quantity and maintaining water quality can often be much more expensive than the costs of retaining natural wetland ecosystem functions.

12. Wetlands and associated ecosystems also regulate the hydrological cycle through taking up water and releasing it into the atmosphere. For example, in the Amazon rainforest, 50% of rainfall is derived from local evapotranspiration. If the forest cover is removed, the area can become hotter and drier because water is no longer cycled between the plants and the atmosphere. This can lead to a positive feedback cycle of desertification, with an increasing amount of local water resources being lost. The cycling of water through the forests, including forested wetlands, is an important service for regulating both local and global climate and maintaining local water resources.

2.2 Transport and tourism opportunities

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[4] IUCN & WWF (1998). Strategic Approaches to Freshwater Management. Background Paper: The Ecosystem Approach. Commission on Sustainable Development 6th Session, New York 20 April-1 May 1998.

13. Wetland ecosystems provide opportunities for tourism through recreation, cultural and aesthetic experience, and reflection. Recreational uses include water sports, fishing, hunting, bird watching, and photography. Since tourism is a leading world business, the economic value of these can be considerable, and the potential of wetlands and their often spectacular wildlife for ecotourism is increasingly being recognized. Maintaining the wetlands and capitalising on these uses, which can bring income to local communities, can be a valuable alternative to more disruptive uses and degradation of these ecosystems.

14. Many riverine wetlands and large lakes are extensively used as major transport and trade corridors for the movement of people and goods between ports and the coast and inland areas of many countries.

2.3 Production

15. Many components of wetland ecosystems provide resources for direct human consumption, including: water for drinking, fish, rice, water plants and fruit to eat, plants and animals for medicinal purposes, reeds to thatch roofs, timber for building, peat and fuel wood for fires.

16. Harvesting ecosystem products while respecting the production rate and the regenerative capacity of each species can provide sustainable benefits to human society. For example, most fisheries rely heavily on healthy wetland ecosystems and their maintenance is often a fundamental requirement for both local and national economies. In many rural areas, water supply depends largely on water extracted from shallow boreholes or local springs. The aquifers and springs can provide water on a sustained basis only if areas of recharge, generally wetlands, are maintained and protected.

2.4 Cultural heritage

17. Wetlands also provide rich centres of culture and heritage (for further information, see also Ramsar's 2001 factsheets on *The cultural heritage of wetlands*, and Ramsar COP8 DOC. 15 and COP8 – DR 19). Many people depend upon the maintenance of natural wetland ecosystems to support their traditional lifestyles and livelihoods. For example, among many southern African peoples a complex set of beliefs exists for water, wetlands, and riparian zones. Many rivers, pools and water sources hold a profound sacred status. Linked to this are numerous traditions such as the annual reed dance of the amaSwazi and institutions such as the immortal rain queen Modjadji. People's dependence on these resources is also reflected in the modern era. For example, Botswana has named its currency, the Pula ("rain"), after one of the most precious resources in an arid region.

3. Managing water for wetland ecosystems

18. In general, the value of wetland ecosystems to water resources management has not been adequately recognized. Huge international investments in water resource management have tended to focus on structural approaches, but with little attention being paid to the role and importance of natural ecosystems in managing the hydrological cycle, or to the potential of wetland ecosystems as naturally-functioning and cost-effective alternatives to costly engineering investments.

19. Very few wetland ecosystems, like the world's environment in general, are now truly natural: almost all are modified and managed, intentionally or unintentionally and to a greater or lesser extent by, for example, flow regulation, channelisation or pollution as well as other land use and land use change pressures. Returning most rivers and wetlands to their natural states would be impossible due to long-established patterns of human use and impacts.

20. Hence, environmental flow allocation cannot be seen as the flow which maintains or returns a river or other wetland ecosystem to its natural state. Rather it is the flow which conserves the functions and attributes of the wetland ecosystem which are desired by people, which in turn secures the sustained availability of the goods and services of the wetland for people.

21. It is essential, for the principle of making water allocations for wetland ecosystems to be implemented with real commitment by governments and stakeholders, that the water allocated to ecosystems should lead to maintaining or enhancing the quality of people's lives, and should not prejudice the provision of basic water supply, sanitation, and food security.

22. However, since freshwater supplies are finite, water for ecosystems must, in almost all cases, be made available from existing water resources. This in turn means that existing water resources must be allocated and managed carefully, and that excessive demands by offstream users should be reduced, in order to ensure that allocations can be made for wetland ecosystems with a reasonable degree of assurance.

23. Setting environmental water allocations is a matter of societal choice, in which all sectors of society should participate. For the millions of people worldwide who depend directly on wetland resources or benefit from wetland functions, providing water for the environment and for people is one and the same. Setting aside a water allocation for wetland ecosystems before authorizing or licensing offstream uses is, and should be widely recognized as, an investment in sustainability, rather than a reduction in economic development.

24. Management of wetland ecosystems requires that management activities take place both within a wetland and in the surrounding catchment [(see also the guidance in Ramsar COP8 – DR 14 concerning management planning for Ramsar sites and other wetlands)]. One of the most important management factors is the allocation of sufficient water of an adequate quality to maintain the desired wetland ecosystem functions. However, it is not sufficient simply to release water from dams or flow control structures to serve as allocations to wetland ecosystems. It is necessary also to consider and manage land-based activities which impact on wetlands, such as commercial forestry (which reduces available runoff at the head of a catchment), damage to riparian zones (which changes patterns of flow and erosion/deposition patterns), and excessive groundwater abstraction (which can lower the water-table and so reduce baseflow to both wetland and terrestrial ecosystems).

25. To ensure that appropriate water allocations are made for, and actually reach, wetland ecosystems, four components are necessary:

 25.1 decision-making frameworks or processes which recognize wetland ecosystems and the critical role they play, and which permit wetland ecosystem functions to be identified and valued in the same context as offstream or direct water uses by people;

25.2 appropriate scientific and technical tools for quantitatively determining appropriate water allocations for the maintenance of desired wetland ecosystem functions;

25.3 comprehensive strategies for the implementation of management measures which will support water allocations for wetland ecosystems; and

25.4 appropriate management tools and measures that can be used to manage people's demands and impacts on water resources so that water remains for, or is made available to, wetland ecosystems.

26. Each of these four components, illustrated with case study examples, is described in the sections that follow.

4. Decision making processes

4.1 Law- and policy-based processes

Conventional law

27. National policy to support the allocation of water specifically to protect and maintain wetland ecosystems is relatively new in most countries where it has been implemented. However, experience is beginning to show that unless water allocations for wetland ecosystems are explicitly mentioned and given a clear status in water policy and legislation, then although water requirements of wetland ecosystems may be determined in studies and environmental impact assessments, water allocations based on these determinations are unlikely to be implemented in practice.

28. It is not sufficient to have the issue addressed only in environmental policy and legislation. Environmental, as well as water, policy and legislation need to be reviewed and harmonised in order to incorporate water allocations for wetland ecosystems. The reviews should be concurrent and preferably closely linked in order to ensure consistency in the policy and legal approaches. The roles and responsibilities of the different ministries or resource management agencies in determining and implementing water allocations to wetland ecosystems must be established, with clear lines of accountability and authority.

29. The specific laws and policies concerning allocation of water to wetland ecosystems vary from country to country, but in general there are three types of situations, described further below, representing progressively higher degrees of protection for wetland ecosystems:

- no explicit provisions for water allocations to wetland ecosystems;
- ecosystems compete with other users for water allocations; and
- ecosystems have water rights in law

Scenario 1: No explicit provisions for water allocations to wetland ecosystems

30. This situation occurs mostly in countries where environmental and/or water policy dates from the mid-1900s or earlier. Here water allocations to wetland ecosystems or to "the environment" are not mentioned at all in water legislation or policy, and are seldom specifically mentioned in environmental legislation unless this legislation is relatively recent.

31. Where the legislation and/or policy does make mention of water allocations to wetland ecosystems, this generally is through regulations relating to Environmental Impact Assessments (EIA), since then ecosystem water requirements can be determined on a project basis during an EIA, for example for a water resources development project.

32. However, even when a water allocation is determined as part of an EIA, this does not necessarily mean that such an allocation will be implemented when the project is

undertaken: whether the allocation is actually made, and the size of this allocation, will depend on the water policy in place at the time.

33. The disadvantage of no explicit provisions being required for water allocations is that it can easily lead to cumulative impacts on wetland ecosystems, whereby each new development project demands "just a little more" water from the ecosystem. Such sequential cumulative allocations can be approved without reference to the overall picture because there is no clear legal status given to wetland ecosystem water allocations – thus water can later be appropriated readily and without due process, to be used for other offstream water uses of perceived higher value (see Case Study 1).

34. Under this scenario, water is usually treated as a private good, and there may or may not be regulatory control over the abstraction of water which is considered to constitute people's "normal share" of the flow or their "riparian right" to water. In cases of over-allocation, lengthy legal processes may be necessary in order to expropriate water for re-allocation to higher value uses or to ecosystems.

35. This system can work successfully when there are no shortages of water and few conflicting demands on water. In water-scarce situations, demarcated areas can be established within which specific water allocation rules apply. For example, under South Africa's previous water legislation (Act 54 of 1956) these were called Government Water Control Areas. Such rules then take precedence over existing water legislation. Wetland ecosystems such as designated Ramsar sites could be protected using this strategy of controlled areas, but review of national water and environmental legislation is generally more effective at ensuring water allocations for wetland ecosystems.

Case Study 1. Las Tablas de Daimiel, Spain

The history of the Tablas de Daimiel wetland in Spain provides an example of how groundwater exploitation has affected the interaction between surface water and the aquifer. The Tablas is a marshland at the confluence of the Rivers Guadiana and Gigüela. At its largest extent, it covered some $15km^2$ with a depth of around 1m. It is one of Spain's two wetland National Parks. This status provides legal protection for the wetland itself, but not for the catchment of the upper Guadiana River which feeds it. The Tablas de Damiel has been designated a Ramsar site and nominated as a UNESCO Biosphere Reserve. The wetland is sustained predominantly by discharge from the western Mancha calcareous aquifer, although surface flow from the Guadiana and Gigüela also helps to support it.

The aquifer has been intensively exploited for the past two decades to provide water for irrigation farming: abstractions have increased from 200 million m^3yr^{-1} in 1974 to 600 million m^3yr^{-1} in 1987. By 1987 the total abstraction was greater than the estimated average recharge to the aquifer from the catchment of 200-300 million m^3 yr^{-1}. This has led to a progressive lowering in groundwater levels of 20-30 metres and greatly reduced flows in the Guadiana river. As a consequence, there has been a change in the hydrological functioning of the Tablas de Daimiel. The decline in the water table has resulted in the conversion of a net groundwater input into the wetland of 45 million m^3yr^{-1} to a net outflow from the wetlands to groundwater of 33 million m^3yr^{-1} (Llamas, 1998). The ecological impact on the wetlands has been devastating, as peats have dried out completely in some places.

An experimental plan to restore the wetland was approved in 1988 by the Spanish Government. This consisted of several actions: a) drilling of emergency pumping wells in the wetland; b) the transfer of up to 60 million m^3 of water from another catchment to the Gigüela; and c) hydraulic structures to control and optimise water levels in the wetlands. The Ministry of Environment prohibited the drilling of new wells and has imposed limitations on pumping from existing wells. In 1992, a programme of incentives to farmers was launched, in order to reduce water consumption. The combined effect of these measures, together with recent good rainfall, has led to the recovery of groundwater levels from a historical minimum of –42.3m in 1995 to the level of –26.5m in 2001.

Scenario 2: Ecosystems compete with other users for water allocations

36. In this scenario, water allocations can be made to wetland ecosystems, but these have the status of authorizations for the use of water, on the same basis as authorizations made to, for example, irrigation farmers or industry. Here the ecosystem is seen as a valid though competing user for the water, and allocations are often made on the basis of the perceived highest value use of the water (often referred to as "beneficial use"). Wetland ecosystems are given protection for the sake of the ecosystems. If a sufficiently high value, such as an important sport fishery or the country's obligations under an international treaty such as the Ramsar Convention, can be demonstrated, then wetland ecosystems will receive appropriate allocations.

37. In this situation, water may be either a private or a public good. If water is treated as a private good then, as in Scenario 1, difficulty may arise if there is a need to expropriate or re-allocate water for wetland ecosystems. Lengthy legal processes may result as water users try to prove higher value, and government may need to buy back ecosystem allocations at "market value", which is not always easy to establish. If water is regarded a public good, then the government may be able to appropriate water or reduce water users' authorizations to make water available for wetland ecosystems.

38. This approach can work to protect ecosystems, but to be truly effective it requires valuation tools which can value ecosystem goods and services in the same context and currencies as commercial or other offstream uses. It also requires a sophisticated water market and pricing strategies. An example of where this approach has been relatively successful is the Murray-Darling Basin in Australia, where water entitlements, including environmental entitlements, are traded on the free market and a system of real-time water accounting is in place (see Case Study 2).

Case Study 2. The Murray Darling Basin

The Murray-Darling Basin is one of Australia's largest drainage divisions, and one of the world's major river systems, ranked fifteenth in terms of length and twenty-first in terms of area. It covers just over one million square kilometres – some fourteen per cent of Australia's continental land area. The Basin includes the Darling River (2,740 km long), the Murray (2,530 km), and the Murrumbidgee (1,690 km) – the three largest rivers in Australia. There are more than 30,000 wetlands in the Murray-Darling Basin, including twelve designated as Ramsar sites.

Most wetlands are small (less than ten hectares in size), but some are immense – over 100,000 hectares.

Threats to the habitats and ecological communities of wetlands in the Basin include increasing salinity, rising water tables, inadequate flooding regimes, drainage, vegetation clearance, invasive species, and barriers to movement of water and biota. Much wetland area has been lost: prior to regulation of the Gwydir River, for example, wetlands were estimated to cover up to 47,000 hectares, but now cover only about 8,400 hectares.

The Basin includes parts of four States: New South Wales, Victoria, South Australia, and Queensland, as well as the entire area of the Australian Capital Territory. Under the Australian Constitution, the Federal or Commonwealth Government is generally not able to take unilateral action in resource management issues – it needs to work with the States and Territories, which have primary responsibility for land and water management.

The Murray-Darling Basin Agreement (1992) provides the institutional framework for the management of the Basin's natural resources and environment. The purpose of the Agreement is "to promote and coordinate effective planning and management for the equitable, efficient and sustainable use of the water, land and other environmental resources of the Murray-Darling Basin".

The Agreement established the Murray Darling Basin Ministerial Council – which brings together the Commonwealth, State and Territory governments. The Murray-Darling Basin Commission is its executive arm – and comprises representatives of the relevant State, Territory and Commonwealth government agencies with responsibility for land, water and the environment. The Ministerial Council is also advised by a Community Advisory Committee.

Major policy initiatives of the Ministerial Council include the establishment of a cap on water diversions and a Sustainable Rivers Audit, the setting of environmental flow and water quality objectives for the River Murray, and the development of a series of strategies addressing specific issues across the Basin such as floodplain management, salinity management, and wetland management.

In response to the loss and degradation of wetlands in the Basin, the Ministerial Council has developed a Floodplain Wetlands Management Strategy. The goal of this Strategy is "to maintain and, where possible, enhance floodplain wetland ecosystems in the Murray-Darling Basin for the benefit of present and future generations".

The Strategy recognizes the ecological importance of wetlands, as well as their biodiversity values. Its objectives include, *inter alia*, to support community initiatives in managing floodplain wetlands, to develop a sound scientific understanding of the physical, chemical and biological processes operating in wetlands, and with the surrounding systems, and to evaluate and manage river flow regimes and water allocations to maintain, restore and enhance floodplain wetlands.

One of the priorities for Commonwealth investment under the Murray-Darling 2001 Program of the Natural Heritage Trust is the restoration of riparian land systems, wetlands, and floodplains by establishing environmental flows capable of sustaining natural processes and protecting the aquatic environment. The Natural Heritage Trust also includes a Wetlands Program, which includes among its priorities:

- completing management plans for Ramsar wetlands;
- actions leading to State government nominations for Ramsar listings;
- survey work to improve coverage and representativeness of State wetland inventories; and
- community-based projects.

An example of how this Program operates is provided by its funding of work in the Gurra Gurra wetland system. Funding of AUS$700,000 has been provided over a period of three years to undertake a variety of work at seventeen sites in this area of the lower River Murray. Early results from the rehabilitation work include a reduction in salinity (caused by the influence of saline groundwater) from 21,000 mS/m (milliSiemens per meter) to 4,000 mS/m, and significant regeneration of native species with return of a drying cycle to a drowned wetland.

Scenario 3: Ecosystems have water rights in law

39. Under this scenario wetland ecosystems have the highest level of protection, and water allocations to wetland ecosystems are a right in law. Wetland ecosystems may be afforded one of two levels of priority:

    - the water required to protect wetland ecosystems has a higher priority than commercial or other uses; or
    - the water required to protect wetland ecosystems has the same priority as other uses.

40. In South Africa the former applies, and there is a clear hierarchy in law and policy which states that if there should be conflicting demands for water, the order of precedence in which these demands should be met is (i) basic human needs, (ii) aquatic ecosystems, (iii) water to meet international obligations in shared river basins, and (iv) other water uses[5].

41. This approach recognizes an aquatic ecosystem as the resource from which the commodity of water is derived rather than merely a competing user of water. Wetland ecosystems are given protection in order to benefit people through sustained provision of ecosystem goods and services, including water. When water allocations amongst many competing users must be decided, this approach is more defensible than the protection of ecosystems for ecosystems' sake, as in Scenarios 1 or 2 above. It ensures the explicit inclusion of ecosystem goods and services in any cost-benefit analysis related to water allocations. Water is usually a public good in this type of scenario, enabling the government to appropriate water for ecosystems, when necessary.

42. Under this scenario, there is a need to remain realistic, especially where the short-term demands of economic development may be pressing, although the long-term requirements for protection of ecosystems are recognized. Flexibility in applying this approach is appropriate, using a classification approach such as that proposed in the EU Water Framework Directive and in the South African water resource classification system. Both allow for different levels of protection for water resources and hence different relative

[5] South Africa (1998). National Water Act (Act 36 of 1998). Republic of South Africa.

water allocations to wetland ecosystems.[6, 7, 8] The classification approach as a tool for determining water allocations is described further in section 4.1.

Customary law

43. Around the world, the traditions, customs and beliefs of indigenous peoples form a foundation for a large body of customary or tribal law. This often provides the context and support for the wise use of natural resources, including wetlands. In southern Africa alone there are over 50 different tribal groups that can have varying customary and interconnected tribal law affecting water resource management.

44. Customary law is generally unwritten law. It is fixed practice under which local communities live in accordance because they regard it as the law. In modern law, custom play a much less important role as a formative source of law.

45. Any assertion of a custom as law has to be proved. The African Charter[9] mentions that the following should be proven before a custom could qualify as law:

- it must be immemorial;
- it must be reasonable;
- it must have continued without exception since its immemorial origin; and
- its content and meaning must be certain and clear.

46. Most customary law regarding natural resources is derived from a long tradition of stewardship of these resources, rather than proprietary rights over them.[10] This tradition of stewardship has recently been "rediscovered" and included in the principles upon which modern sustainability and wise use concepts are based. Both individual and communal rights to the use, but not necessarily the ownership, of natural resources may be allowed for in customary law.[11]

47. The fact that customary law is "immemorial" usually means that it has developed over a very long time to be ideally suited to local natural resource conditions, and can take account of local variability, for example flood-drought cycles. It is usually also well understood by the local communities whose activities impact on the wetland ecosystems and water resources they use.

48. Customary law, especially that relating to the use of natural resources such as wetland ecosystems, can be very complex, but this complexity usually makes the law inherently flexible, adaptive and applicable to a wide variety of local situations.

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[6] DWAF (1997). White Paper on a National Water Policy. Department of Water Affairs and Forestry, Pretoria, South Africa.
[7] DWAF (1999). Resource Directed Measures for Protection of Water Resources Version 1.0 Volume 2: Integrated Manual. Department of Water Affairs and Forestry, Pretoria, South Africa.
[8] European Commission (2000). Water Framework Directive. Directive 2000/60/EC of the European Parliament.
[9] African Charter (1998) African commission on human rights. www.doj.gov.za/docs/policy/afr-charter01a.html
[10] Field-Juma, A (1996). Governance and sustainable development. In: Juma C & Ojwang JB (eds.) *In Land We Trust: Environment, Private Property and Constitutional Change.*. African Centre for Technology Studies Environmental Policy Series No. 7, Initiatives Publishers, Nairobi, 1996.
[11] Ramazotti M (1996). *Readings in African customary water law.* FAO Legislative Study, Development Law Service, FAO, Rome.

49. Although very little of the body of customary law relating to water resources has been documented, it is clear from the outcomes of various customary decision-making processes that there is considerable potential for learning from and applying its approaches in modern-day resource management decisions.[12, 13, 14,15]

50. Customary law may not always be appropriate for modern development scenarios, since it has often been adapted progressively over time to suit very specific local situations. However, local customary decision-making processes related to the wise use of wetland ecosystems should be investigated and incorporated, where appropriate, into formal decision-making related to water allocations and to the ongoing use and management of water resources. This goes further than simply recording local communities and indigenous people's knowledge of an ecosystem, and ensuring full participation by local communities and indigenous people's in management and decision-making is recognized in the Ramsar Convention' guidance as a vital element in securing the conservation and wise use of wetlands (see notably Resolution VII.8 *Guidelines for establishing and strengthening local communities' and indigenous people's participation in the management of wetlands*, [COP8 – DR 14 *New guidelines for management planning for Ramsar sites and other wetlands*, COP8 – DR1 *Guidelines for the allocation and management of water for maintaining the ecological functions of wetlands*, and COP8 – DR19 *Guiding principles for identifying cultural aspects of wetlands and incorporating them into the effective management of sites*]. Fully incorporating the tenets of customary law into water resource management is likely to improve the sustainability of water resource development projects, as well as to strengthen the ecosystem protection component of management plans and policies.

Case Study 3. Customary law and water management in southern Africa

African spirituality and legend is tightly bound into tribal beliefs, customs, behaviour and law. Water itself is regarded by many traditional Africans as a living force and medium for purification and healing. Traditional healers who are persons of spirit play an important role in tribal law administration. Recently, in KwaZulu-Natal (South Africa) an ancient day of rest for the region's water spirit, "the great princess iNkosazana", was re-instated by some rural communities. The princess had visited some individuals to complain that she needed the rivers left completely alone so she could enjoy and renew them without disturbance. On this ancient day of rest, now ruled as Mondays and Saturdays, utilizing any water directly from the river is strictly prohibited.

In 1995 Juliana, a Zimbabwean prophetess, instituted a set of strict taboos which the community had to observe in order to bring back the water spirits into the region, who would then break a current drought. Among these taboos was the banning of the construction of dams and the

[12] Goodman, E, J 2000 Indian Tribal Sovereignty and Water Resources: Watersheds. Ecosystems and Tribal Co-management. In: *Journal of Land Resources and Environmental Law*. No 185

[13] Chabwela H, Mumba, W (1998). Integrating Water Conservation and Population Strategies on the Kafue Flats, Zambia. www.aaas.org/international/psd/waterpop/Zambia.htm

[14] Gillingham M (1999). Gaining Access to Water: Formal and Working Rules of Indigenous Irrigation Management on Mount Kilimanjaro, *Tanzania. Natural Resources Journal* V39, Part 3, pp419-441.

[15] Craig D & Freeman, S (1998) Indigenous Law Resources, Reconciliation and Social Justice Library. Indigenous Governance of the Inuit of Greenland. www.austlii.edu.au/au/other/indigLRes/1998/3/8.html

prevention of the use of soaps and metal containers in the river. Thousands of people adhered to her pronouncements and restrictions, which provides a powerful example of the respect and importance of spiritual beliefs in influencing traditional water management[16].

4.2 Valuation-based processes

51. To determine the best use of water, an independent measure of the benefits of various alternative options is required[17]. Monetary value is frequently employed, since this is how most goods and services are exchanged in everyday life.

52. Here the aim is to allocate water to those uses that yield an overall net gain to society, as measured in terms of the economic benefits of each use, minus its costs. This is termed *economic efficiency*. For example in northern Nigeria, large dams were constructed on the Hadejia river to feed intensive irrigation, which led to a reduction in the Hadejia-Nguru wetlands downstream.[18] However, it has been demonstrated[19] that the economic value of the water when used for intensive irrigation was many times less than its value for supporting fisheries, agriculture and fuelwood in the wetlands downstream. Consequently, the Nigerian government is now exploring the potential for releasing water from the dams to restore the wetlands.[20] Economic valuation thus provided a sound basis for water management decision making. This example of the power of valuation is further described in Case Study 4.

53. However, economic valuation is not a panacea for decision-makers facing difficult choices. One problem that arises is that the question of which stakeholders gain and which lose from a particular water management scheme is not a criterion taken into account in efficiency assessment. Such distributional effects may be very important, since although a particular scheme may show a substantial net benefit and would be deemed highly desirable in efficiency terms, the principal beneficiaries may not necessarily be the ones who bear the burden of the costs or suffer any adverse impacts which arise. For example, the Kariba dam, built in 1959, was the first of the major dams in Africa and brought a great benefit to Zambia through its supply of power for copper mining. However, since no plans for rural electrification were made, the 50,000 Batongans displaced by the reservoir bore the burden of the costs, but saw none of the benefit[21].

54. A further difficulty facing valuation of water is that there is generally insufficient quantitative information available about the ecological and hydrological processes of

[16] Bernard, P (2000) Water Spirits, Indigenous Peoples Knowledge Programme, *South African Wetlands Journal* No 11, pp12-16.
[17] Barbier, E.B., Acreman, M.C. & Knowler, D. (1997). *Economic valuation of wetlands: a guide for policy makers and planners*. Ramsar Convention, Gland, Switzerland.
[18] Hollis, G.E., Adams, W.M. & Aminu-Kano, M. (1995) (Eds*) Hadejia-Nguru Wetlands and wetland management in sub-Saharan Africa*. IUCN, Gland, Switzerland.
[19] Barbier, E.B. Adams, W.M. and Kimmage, K. (1991). *Economic Valuation of Wetland Benefits: the Hadejia-Jama'are Floodplain, Nigeria*. London Environmental Economics Centre Paper DP 91-02. International Institute for Environment and Development, London, UK.
[20] Hadejia-Nguru Wetlands Conservation Project/National Institute for Policy and Strategic Studies (1993). *Proceedings of the workshop on the management of the water resources of the Komodugu-Yobe basin*. National Institute Press, Kuru, Nigeria.
[21] Acreman, M.C. 1996 Environmental effects of hydro-electric power generation in Africa and the potential for artificial floods. *Water and Environmental Management,* 10, 6, 429-435.

wetlands, such as their nutrient recycling and groundwater recharge functions. If this information is lacking, considerable investment of time, resources and effort in further scientific and economic research is required, since these vital processes and functions must be quantified before economic value can be assigned to them.

55. Finally, some members of society may argue that certain environmental systems, such as a tropical rainforest, may have an additional 'pre-eminent' value in itself, beyond that which it may provide in terms of satisfying human preferences. This is particularly significant for water management, here management decisions may lead to the degradation of essential life-support functions of ecosystems, such as nutrient cycling or loss or the decline of rare species. From this perspective conserving an ecosystem or species is a matter of moral obligation rather than related to an efficient, or even fair, allocation of the water. Thus, economic values represent just one input into water management decision-making, alongside a number of other important considerations.

Case Study 4. Valuation in the Hadejia-Jama'are River Basin, Northern Nigeria

In Northern Nigeria, an extensive floodplain exists where the Hadejia and Jama'are Rivers converge. The floodplain provides essential income and nutritional benefits in the form of agriculture, grazing resources, non-timber forest products, fuelwood, and fishing for local populations, and it helps to recharge the regional aquifer which serves as an essential groundwater source.

In recent decades the ecosystem functions of the floodplain have come under increasing pressure from the construction of the Tiga and Challawa Gorge dams upstream. The maximum extent of flooding has declined from 300,000 ha in the 1960s to around 70,000 to 100,000 ha more recently. Furthermore, there are plans for a new dam at Kafin Zaki.

Economic analysis of the Kano River Project, a major irrigation scheme benefiting from the upstream dams, and the floodplain showed that the net economic benefits of the floodplain (agriculture, fishing, fuelwood) were at least US$ 32 per 1000 m^3 of water (at 1989 prices). However, the returns in terms of crops grown in the Kano River Project were at most only US$ 1.73 per 1000 m^3, and when the operational costs were included the net benefits of the Project were reduced to only US$ 0.04 per 1000 m^3.

A combined economic and hydrological analysis was conducted to simulate the impacts of these upstream projects on the flood extent that determines the downstream floodplain area. The economic gains of the upstream water projects were then compared to the resulting economic losses to downstream agricultural, fuelwood and fishing benefits.

Given the high productivity of the floodplain, the losses in economic benefits due to changes in flood extent for all scenarios are large, ranging from US$2.6 - 4.2 million to US$23.4 - 24.0 million. As expected, there is a direct trade-off between increasing irrigation upstream and impacts on the floodplain downstream. Full implementation of all the upstream dams and large-scale irrigation schemes would produce the greatest overall net losses, around US$20.2 - 20.9 million.

These results suggest that the expansion of the existing irrigation schemes within the river basin is effectively 'uneconomic'. The introduction of a regulated flooding regime would reduce the scale of this negative balance substantially, to around US$15.4 - 16.5 million. The overall combined value of production from irrigation and the floodplain would, however, still fall well below the levels experienced if the proposed additional upstream schemes were not constructed.

5. Tools for determining water allocations for wetland ecosystems

5.1 Water for ecosystems – concepts and principles

56. In many river basins throughout the world, water resources and wetland ecosystems have already been substantially modified by human utilization and development, and they no longer function in anything like their natural ecological state. However, a water resource does not have to be in a pristine or untouched state to have ecological integrity and resilience – even modified wetland ecosystems can have the resilience which makes them renewable resources, so long as they are managed in such a way that a certain level of ecological function and integrity is either maintained or rehabilitated.

57. Sustainable utilization requires achieving a balance between an acceptable level of long-term protection of water resources and water users and society's present requirements for economic growth and development. The total prevention of abstraction or of pollution is an ideal to strive for in the long term, but it is seldom, if ever, practical in the short to medium term, since neither the emission of waste to the water environment nor the impacts of land use and land use change on the water environment can be prevented entirely.

58. However, these damaging pressures can and must be managed and regulated in order to achieve adequate long-term protection of water resources. To manage and regulate impacts on water resources, clear objectives are required which establish the level of protection which should be afforded to water resources, the level of ecological integrity which must be maintained, and the water allocation which will ensure that the desired levels of protection and ecological integrity are met.

59. For the purposes of this paper, the water allocation to a wetland ecosystem is defined as:

> *"the water quantity and water quality required to maintain a particular ecological character*[22] *of the water resource which will sustain selected wetland ecosystem functions and services."*

Environmental objectives for water resources and wetland ecosystems

60. In the context of the Ramsar Convention, certain wetland ecosystems may be delineated and identified as requiring a high level of protection, notably through their designation as Wetlands of International Importance (Ramsar sites).

61. However, since these wetland ecosystems, especially inland wetlands, are integral parts of a larger catchment basin system, it is not sufficient to set management objectives for the maintenance of the ecological character only the wetland ecosystem itself: it is absolutely necessary to identify linkages between the particular wetland ecosystem and the other water

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22 The Conference of the Parties of the Ramsar Convention has defined "ecological character" as *the sum of the biological, physical and chemical components of the wetland ecosystem and their interactions which maintain the wetland and its products, functions and attributes* (Resolution VII.10).

resources in the catchment which are in hydraulic or ecological connectivity with that wetland ecosystem[, as indicated in the Ramsar Convention's guidance on wetland management planning (COP8 - DR14)]. Management objectives must be set also for the hydrologically-linked water resources, and these objectives must be consistent with and integrated with the objectives set for the specific wetland ecosystem being managed.

62. It is also important to recognize that, particularly in large catchments, there are likely to be a number of wetlands identified as Ramsar sites and/or as protected areas designated under other instruments, and every effort should be made to harmonise their management objectives so as to contribute fully to the sustainable water resource management of the whole catchment. This can also require cooperation and coordination between countries where catchments cross geo-political borders (see also Ramsar guidance on such matters, notably Resolution VII.18 on integrating wetland conservation and wise use into river basin management and Resolution VII.19 on international cooperation).

63. Management objectives for water resources need to reflect the broader definition of a water resource as an ecosystem, otherwise the ecological integrity of water resources will not be fully sustained. In order to reflect an ecosystem approach, objectives for water resources should be "environmental" objectives, which address all components of the aquatic ecosystem in order to ensure its maintenance, rather than simply water quality objectives or flow objectives.

64. Since environmental objectives are a statement of environmental quality to be achieved in order to maintain an identified level of ecological integrity in a water resource, environmental objectives for water resources should have four critical components, to cover each of the aspects of ecological integrity which are necessary for protection of aquatic ecosystems:

64.1 **Requirements for water quantity**, usually stated as Instream Flow Requirements for a river reach or estuary, or water level requirements for standing water or groundwater. These are set according to accepted procedures for determining water quantity allocations to wetland ecosystems;

64.2 **Requirements for water quality**, including physical, chemical and biological aspects of water quality. These should be determined according to accepted water quality guidelines or criteria;

64.3 **Requirements for habitat integrity**, which encompass the physical structure of instream and riparian habitats, as well as aspects of their vegetation; and

64.4 **Requirements for biotic integrity**, which reflect the health, community structure, and distribution of aquatic biological diversity.

65. Environmental objectives for water resources are scientifically derived criteria, based on the best available scientific knowledge and understanding. They represent our best assessment of the environmental quality or ecological character which is necessary to provide a desired level of protection to a water resource. Environmental objectives should be derived for individual wetlands or water resource components, such as river reaches, sub-catchments, estuaries, coastal marine waters, wetlands or groundwater resources, within the broader framework of objectives for the catchment.

Risk-based objectives and classification

66. It is especially important to recognize that the water allocation to a water resource or to a wetland ecosystem is not just the minimum water quantity and water quality required for protection.

67. For a water resource which is classified as being of high protection status, the allocation would be set at a higher level than the minimum, which would correspond to the idea of minimum risk and maximum caution. For a water resource which is assigned lower protection status, the allocation would be set at a level which should still afford protection to the resource, but without the benefit of the buffer which such caution provides.

68. However, it is simplistic to assume that a "higher" allocation necessarily means that only a greater quantity of water is allocated to protection of the resource. The assurance or reliability of water, especially under extreme climatic conditions, is just as critical an aspect of the allocation as its quantity and quality.

69. The protection status which is afforded to a wetland ecosystem depends on three aspects of its importance:

- ecological importance and sensitivity;
- social importance, and
- economic importance.

Ecological importance and sensitivity

70. The ecological importance of a river is an expression of its importance to the maintenance of ecological diversity and functioning on local and wider spatial scales, including the ecological character of wetlands in the catchment. Ecological sensitivity (or fragility) refers to the system's ability to tolerate disturbance and its resilience – its capacity to recover from disturbance once it has occurred.

71. In determining water allocations, the following ecological aspects form the basis for the estimation of a river's ecological importance and sensitivity:

71.1 the presence of rare and endangered species, unique species (i.e., endemic or isolated populations) and communities, species sensitive to disturbance, and species diversity;

71.2 habitat diversity, including specific habitat types such as river reaches with a high diversity of habitat types, i.e., pools, riffles, runs, rapids, waterfalls, riparian forests, etc.;

71.3 the importance of the particular resource unit (e.g., river or reach of river) in providing connectivity between different sections of the whole water resource, for example whether it provides a migration route or corridor for species' movement;

71.4 the presence of protected areas and other relatively natural areas along the river section; and

71.5 the sensitivity (or fragility) of the system and its resilience to environmental changes of both the biotic and abiotic components of the ecosystem.

Social importance

72. Features which should be included in the assessment of social and cultural importance are:

    72.1 the extent to which people are dependent upon the natural ecological functions of the water resource for water for basic human needs (e.g., as the sole source of water supply);

    72.2 dependence on the natural ecological functions of water resource for subsistence agriculture or aquaculture;

    72.3 the use of the water resource for recreation;

    72.4 the historical and archaeological value of the water resource;

    72.5 the importance of the water resource in rituals and rites of passage;

    72.6 the presence of sacred or special places in the river (e.g., where spirits live);

    72.7 the use of riparian plants for building or craft materials, traditional medicine and food; and

    72.8 the intrinsic and aesthetic value of the water resource for those who live in the catchment and those who visit it.

Economic importance

73. Water resources are usually important from an economic point of view. The economic value of a water resource is traditionally assessed in terms of the amount of water which can be abstracted for offstream use. Typical indicators include the number and value of jobs generated by the use of the water or the amount of revenue generated.

74. However, it is important to recognize that water resources also provide other services which are often not included in economic valuation. In particular this applies to the services and benefits provided by aquatic ecosystems. These can include, *inter alia*:

    74.1 transport and/or purification of biodegradable wastes;

    74.2 recreation and aesthetic opportunities;

    74.3 food production;

    74.4 flood attenuation and regulation; and

    74.5 water-based transport.

75. While the development of tools for quantitative valuation of ecosystem services and benefits is still in an early stage, it is necessary that all the potential economic values of a water resource at least be identified when assessing economic importance.

Case Study 5. Community-based water allocation in the Phongolo River

In the late 1960s the Pongolapoort dam was constructed on the Phongolo River in northeast South Africa near its borders with Swaziland and Mozambique. The reservoir was filled in 1970 with a view to irrigating 40,000 hectares of agricultural land for white settlers, with no provision for hydropower generation.

No assessments were undertaken of impacts of the impoundment on the floodplain, where 70,000 Tembe-Thonga people were dependent on recession agriculture, fishing and other wetland resources, nor of the biodiversity of the Ndumu game reserve. In the event very few settlers came to use the irrigation scheme. The dam changed the whole flooding regime of the river, which had significant negative impacts on agriculture and fisheries.

In 1978 a workshop was held on the Phongolo floodplain to review the future of irrigation and how to minimize the negative impacts on floodplain. This led to a plan for controlled releases of water to rehabilitate the indigenous agricultural system and the wildlife. However, initial releases of water from the dam were made at the wrong time of the year and crops were either washed away or rotted.

In 1987 the Department of Water Affairs and the tribal authorities agreed to experiment with community participation. As a result, water committees were established representing five user groups: fishermen, livestock keepers, women, and health workers (both new primary health care workers and traditional herbalists and diviners). They were given the mandate to decide when flood waters should be released. These committees have been very successful at implementing people's views and their work has led to management of the river basin to the benefit of the floodplain users.

Case Study 6. Classification systems for water resources

Under a national classification system, water resources can be grouped into classes representing different levels of protection. The risk which can be accepted in each class is related to the level of protection required for that class. This provides a nationally consistent basis and context for deciding on an acceptable level of short-term risk, against the requirements for long-term protection of a water resource.

For water resources which are especially important, sensitive, or of high value, little or no risk would be acceptable, and they would be assigned a high protection class. In other cases, the need for short- to medium-term utilization of a water resource may be more pressing: here the resource would still be protected, but would be assigned a class which reflected a higher risk. In addition, certain activities or impacts would be regulated or controlled to a certain degree in each class. Some activities, because of their high impacts, might be prohibited entirely in the highest protection class.

The purpose of a classification system is to provide a set of nationally consistent rules to guide decision making about water resources - what we will allow to happen in our water resources, and what we will not. A national classification system allows for transparency, accountability and long term goal-setting to be incorporated into water resources management. Water resources which need to be improved can be identified, and the necessary control measures can be implemented to meet the requirements associated with the assigned class.

National and regional policies and plans taking a classification approach include the South African water policy,[1] which makes provision for a national water resource classification system, the EU Water Framework Directive[5], and the South Australian Water Plan[*].

* South Australia State Water Plan 2000
http://www.dwr.sa.gov.au/publications/pdfs/swp2000.pdf

5.2 Methodologies for determination of water allocations to wetland ecosystems

76. Design specifications for methodologies to determine water allocations for wetland ecosystems require that methodologies:

76.1 be legally defensible, since they must serve as a basis for control and management of impacts and for issuing legally valid water use authorizations and licenses;

76.2 be scientifically defensible and based upon sound ecological principles in line with the integrated ecosystem approach to water resource management;

76.3 match administrative requirements, i.e. that the information be provided to the water resource management agencies in a format which can be used as a basis for drawing up water use allocation plans and catchment management strategies, as well as for setting individual water use license conditions;

76.4 allow for the determination of conservative estimates of the water quantity and quality required to protect a wetland ecosystem, in line with the precautionary approach;

76.5 be derived from available technologies (preferably technologies published in the scientific literature) and knowledge in the region in which the wetland ecosystem is situated, since this will increase the scientific validity and acceptance, and also because it is generally more likely that there will be more specialist capacity available to implement procedures or approaches which are already in use; and

76.6 utilize a holistic ecosystem endpoint, rather than focusing only on a hydrological or chemical endpoint.

77. When determining environmental objectives for wetland ecosystems, and in particular in determining the water allocation, it is necessary to select management objectives towards which the ecosystem is managed (for further guidance on setting management objectives for wetlands, see the Convention's guidance on management planning for Ramsar sites and other wetlands ([COP8 – DR14]). A water allocation would then be set which would contribute to achieving these objectives.

78. For reasons of scale and resolution, the endpoints for environmental objectives are generally defined for the abiotic components of the ecosystem. For practical purposes, it is assumed that if an adequate abiotic template can be provided, then the biotic components of the ecosystem (its fauna and flora) will be maintained and protected.

79. The abiotic template consists of three components:

    79.1 the *hydraulic habitat*, which is measured by the parameters of water depth, wetted perimeter, and flow velocity;

    79.2 the *physico-chemical habitat*, which is measured by typical water quality parameters such as pH, temperature, nutrient concentrations, and concentrations of toxic substances; and

    79.3 the *geomorphological habitat*, which includes the morphology of the channel, substrate types and distribution (but also including the biotic component of riparian vegetation).

80. In general, methodologies for the determination of water allocations for river ecosystems are more developed than for estuarine ecosystems, palustrine wetlands, and those systems which are fed exclusively or largely by groundwater. Where water allocations have been made for such systems, the determination has usually been through very site-specific studies, and few generally applicable methodologies are available. South Africa has published guidelines for determination of the flow requirements of estuaries and palustrine wetlands, and for the groundwater contribution to wetland ecosystems, but these have yet to be fully tested and developed[23].

Rapid methods

81. Rapid methods are here taken to be desktop studies using existing available data and information, without further field data collection. There are many rapid methods available for estimation of water allocations for wetland ecosystems.[24].

82. Most such methods are based on the establishment of an empirical relationship between the water flow in a river or channel (as water volume per unit of time) and the resulting structure and function of the associated wetland ecosystem. These methods generally require hydrological data for virgin and present-day runoff, with at least annual resolution. Some methods attempt to provide greater accuracy by linking various hydrological statistics to ecosystem structure and function, but in either case the methods are usually subjective and provide only coarse answers, at the resolution of annual volumes, a proportion of mean annual runoff, or average monthly flows.

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[23] DWAF (1999). Resource Directed Measures for Protection of Water Resources. Volume 4: Wetland ecosystems, Volume 5: Estuarine ecosystems and Volume 6: Groundwater component. Department of Water Affairs and Forestry, Pretoria, South Africa.

[24] Tharme R (1996). Review of international methodologies for the quantification of the instream flow requirements of rivers. Draft report to the Water Research Commission, Pretoria, South Africa.

83. Neither annual nor monthly resolution is sufficient for actually managing flow releases for wetland ecosystems on a daily basis. Nevertheless, this kind of coarse-scale information can be very useful in planning at the catchment or river basin scale.

84. One of the best-known rapid methodologies is the so-called "Montana method"[25], in which the proportion of the virgin mean annual runoff provided to a river ecosystem can be related empirically to the ecological condition of that ecosystem. This methodology relies on observations of ecological condition made by its developer in many North American rivers. However, the method is suitable only for northern temperate ecosystems and cannot be applied with confidence elsewhere, especially in ecosystems where flows are strongly seasonal. A modified version of the "Montana method" has been developed recently in South Africa based on experience from local studies, and this has been extensively used for planning purposes and in the scoping phase of Environmental Impact Assessments[26].

Comprehensive methods

85. A range of more comprehensive methods is available for determination of water allocations for wetland ecosystems. These provide answers at a higher spatial and temporal resolution than the rapid methods described above. Spatial resolution is at river reach level or smaller, and temporal resolution ranges from monthly to daily flows.

86. Application of these methods in a specific river system can take between several months to several years, since they are generally data-intensive, require detailed ecological and hydrological surveys, and usually involve multi-disciplinary teams in numerical modelling studies.

87. Many of these methods use habitat-based objectives. Ecologists provide recommendations regarding the extent, distribution and character of available habitat which is required to maintain or protect certain ecological functions or key species, and then determine, with the help of hydrologists, the necessary magnitude, frequency, duration, and timing of flows which will provide these habitats.

88. Two aspects of habitat, the hydraulic and geomorphological habitat, are usually addressed in the determination process, with the physico-chemical habitat sometimes also being integrated into a determination. Typically, a determination involves intensive hydraulic calibration and modelling to convert the ecological parameters of water depth, wetted perimeter, and water velocity at key sites in the river system to the hydrological parameters of flow rate and flow volume.

89. The best-documented more comprehensive methods are:

89.1 the Building Block Methodology[27] which was developed and has been applied extensively in South Africa;

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25 Tennant DL (1976). Instream flow regimens for fish, wildlife, recreation and related environmental resources. *Fisheries* 1(4): 6-10.

26 DWAF (1999). Resource Directed Measures for Protection of Water Resources: Volume 3 River Ecosystems. Department of Water Affairs and Forestry, Pretoria, South Africa.

27 King JM, Tharme RE & de Villiers MS (2001). Environmental Flow Assessments for Rivers: Manual for the Building Block Methodology. Water Research Commission Report TT131/00, Pretoria, South Africa.

89.2 the Instream Flow Incremental Methodology (IFIM) [28] which is widely used in the USA; and

89.3 the holistic approach, which has been applied in Australia[29].

Case study 7. A generic methodology for determining the water requirements of wetland ecosystems

In South Africa, a generic methodology has been developed for determination of the water requirements of wetland ecosystems[23]. It can be applied to riverine, estuarine, palustrine, and floodplain ecosystems, and involves the following steps.

1. Delineate the boundaries of the study area, which includes both the wetland ecosystem and its catchment.

2. Within the study area, delineate separate resource units. Resource units are sub-areas of the study area, such as river reaches, that are ecologically homogeneous in nature.

3. Determine the ecoregional type of each resource unit, identifying its natural template of biophysical characteristics. For example, in the South African ecoregional classification system, a resource unit might have ecoregional type 6.01: it is in the Lebombo Uplands; hills with moderate relief, undulating rocky terrain; altitude 150-500m; vegetation type Lebombo Arid Mountain Bushveld; rainfall 400-950mm. All riverine wetland ecosystems within ecoregion 6.01 could be expected to display similar natural ecological character, which allows extrapolation of knowledge about the ecological character of a data-rich ecosystem to a data-poor ecosystem in the same ecoregion.

4. On the basis of the ecoregional type, describe the reference conditions for each resource unit. Reference conditions are the expected natural, unimpacted, ecological character. These serve as a baseline against which to measure present-day ecological character.

5. Determine the present ecological character of each resource unit, in order to assess the degree of change or degradation from natural conditions, the current trajectory of change, the factors influencing change or degradation, and the present and possible future uses of the resource unit.

6. In consultation with stakeholders, decide what the desired future state of each resource unit should be, in terms of ecological character and uses to be sustained, and the level of protection required for the wetland ecosystem of that resource unit. The desired future state of the wetland ecosystem which was the original subject of the study will be the determining factor in setting the desired future state for all upstream resource units.

7. On the basis of the desired future state, use one of the scientific methods (such as the Building Block Methodology[24] or Instream Flow Incremental Methodology[25]) to determine

[28] Instream Flow Incremental Methodology http://www.mesc.usgs.gov/rsm/IFIM.html

[29] Tharme RE (1996).Review of international methodologies for the quantification of the instream flow requirements of rivers. Draft report to the Water Research Commission, Pretoria, South Africa.

water quantity and water quality conditions which will ensure that the desired ecological character is maintained in each resource unit.

Case Study 8: Lower Indus Delta flow requirements

The Indus is one of the major river systems of Asia and dominates the landscape and economy of Pakistan, providing water for the world's largest irrigated area. The lower Indus supports a large floodplain that provides timber products, especially pit-props for the mining industry. Where the river joins the sea an extensive delta has formed, stabilised by mangroves. These provide camel fodder and fuelwood and support an extensive fishery (with a foreign exchange earning of over US$100 million in 1997), as well as many rare and endangered species. Fresh groundwater within the delta supports communities of fisherfolk and camel herders.

Records from the nineteenth century suggest that freshwater flows to the lower Indus were around 150 million acre feet (MAF) per year (185,000 million m^3). Some flow occurred all year round, with higher flows starting in March, peaking in August, and declining in November. Since then, construction of dams and barrages for irrigation has reduced the flows of water and sediment. During the period 1960-1971, freshwater inflows were only 35 MAF (43,000 million m^3) and the Indus Water Accord only provides 10 MAF (12,300 million m^3) per year. This occurs mainly in the period June-August, with little or no flow in other months.

Ecological studies by the Sindh Forest Department estimated that each 100 acres (40 ha) of mangrove forest requires a flow of 1 cusec (0.028 m^3 sec^{-1}) during July and August to remain healthy and support the associated fisheries. For the estimated 260,000 ha of mangroves a total volume of 27 MAF (33,300 million m^3) would be needed. A typical hydrograph shape would suggest a flow peak of 5,000 m^3 sec^{-1}. The floodplain forests need to be inundated at least twice in every five years to enable saplings to become established.

However, low rainfall in recent years, combined with a rapidly increasing population requiring more irrigated food upstream, means that even the 10 MAF agreed in the Indus Water Accord is unlikely to be released to the delta in the coming years. This implies that the ecological character of the mangrove forests and the goods and services, notably fisheries, they provide will continue to deteriorate.

6. Development of strategies for implementation of water allocations to wetland ecosystems

90. It is not sufficient merely to conduct determinations of the water requirements of wetland ecosystems, no matter how detailed and intensive the studies. It is also necessary to develop site-specific long-term strategies for implementing and managing water allocations for wetland ecosystems.

91. Implementation strategies should:

- set out clear targets and objectives;
- provide explicit time frames within which these targets should be achieved;

- establish the means through which targets will be achieved; and
- identify clearly the roles and responsibilities of government agencies, non-government organizations, stakeholders and water users in implementation.

6.1 Considerations to be addressed in implementation strategies

Socio-economic impacts

92. There may be significant socio-economic impacts associated with the implementation of a water allocation for a wetland ecosystem. Some of these impacts may be positive, for example in improving the potential of the wetland ecosystem to be utilized for subsistence purposes such as farming or fishing. Others may be negative relative to an existing situation, for example a reduction in water allocation for irrigation or industry in order to make water available for the wetland ecosystem.

93. In many cases, where a wetland ecosystem is already impacted, or is threatened by excessive water use or impacts on the water regime, measures to provide water for the wetland ecosystem will have to be phased in gradually over a period of time, in order to avoid serious negative impacts on the local economy.

94. Since it is likely that people in the catchment may have to change the ways in which they use water, and possibly the ways in which they dispose of waste, it is necessary to ensure the full support of water users and stakeholders for the measures which are to be put in place to implement the water allocation for a wetland ecosystem. This can be achieved by establishing a transparent and fully participatory decision-making process right from the start, so that there is agreement on the management objectives for the wetland ecosystem, as well as an understanding and acceptance of the costs and benefits of implementing the water allocation for the wetland ecosystem.

Technology and cost

95. Particularly in a catchment where water resources are already under pressure from over-exploitation, there may be various technological and management alternatives for making water available for allocation to a wetland ecosystem. These can include:

    95.1 imposition of water restrictions or use of disincentives such as increased water tariffs in order to reduce current levels of demand;

    95.2 instituting water conservation and demand management programmes in the catchment in order to reduce overall abstraction and ensure that more water is available for the wetland ecosystem;

    95.3 structural options such as building a dam to store water and make dedicated releases for a wetland ecosystem or inter-basin transfer of water;

    95.4 rehabilitation of degraded catchment areas, prevention of soil erosion, and removal of alien vegetation which reduces runoff.

96. The costs of technological alternatives must be taken into consideration and weighed against the benefits they will generate, in terms of the overall economic welfare of people in the catchment. It is important to recognize that some technologies employed in developed countries may not be sustainable in a developing country context.

Capacity for implementation

97. The available capacity, including resources for implementation, must also be considered when developing an implementation strategy. For example, there would be little value in developing a complex water use licensing and control system if there were insufficient organizational capacity to monitor and enforce license conditions. In such a case, introducing education and awareness programmes and incentives for water conservation may be far more effective in making the necessary water available to meet the allocation for the wetland ecosystem.

6.2 Monitoring and information

98. Establishing a monitoring regime is an essential part of implementing a changed water allocation to a wetland ecosystem. Implementation can be successful only if it is based on sound information, the results of monitoring assessed to establish the success of the implementation in achieving its objectives, and as necessary adjusting the implementation programme. Further Ramsar guidance on establishing a monitoring programme for a wetland ecosystem is available in Resolution VI.1 [and COP8 – DR14].

99. Information requirements for implementation include those related to:

- hydrology, to ensure that the water allocation is being delivered as it was designed;
- water quality;
- ecological character, in order to ascertain and monitor the response of the wetland ecosystem to the new flow regime;
- water use and the compliance of water users with any licence conditions; and
- economic well-being of water users and stakeholders, in order to ensure that the costs and benefits of implementing the water allocation are equitably distributed.

100. The water allocation for a wetland ecosystem is usually designed to mimic, as closely as possible, the natural flow regime. In a regulated catchment, where flow releases for wetland ecosystems are made from dams, it is critical that the timing of the flow releases is close to natural, especially for the small and medium-sized floods which provide important cues for ecological processes such as migration and spawning. Thus real-time monitoring of rainfall and/or flows at an unimpacted site upstream of the point from which the releases are made is usually necessary, in order to match the timing of the releases with the flows which would have been observed under natural, unregulated conditions. If an unimpacted upstream site cannot be found, then it may be appropriate to use an equivalent site in a neighbouring catchment for this purpose.

6.3 The need for an adaptive approach

101. Determination of the water requirements of wetland ecosystems is usually based on the best available information and knowledge, but even with such knowledge it is seldom possible to predict accurately the response of a wetland ecosystem to changes in the flow regime or the water quality regime. Hence it is necessary when developing implementation strategies to allow for an adaptive approach to be taken, whereby the water allocation is implemented, the response of the system is monitored over time, and this is followed by regular review of the new information and modification of the flow regime or water quality regime if this is shown to be necessary.

7. Management tools for the implementation of water allocations to wetland ecosystems

102. Traditionally, water resource management has dealt primarily with the development of the water resources, usually to supply water of a given quality where it was needed, on demand. This approach is based on the assumption that water is an infinite resource, which is clearly not the case in many catchments.

103. Water resource management now must be approached from the perspective that freshwater is a finite resource, and that the demands on freshwater are ever increasing. Furthermore, water is itself only one component of a large and complex catchment ecosystem. It is this ecosystem which provides us not only with the water, but also with many other goods and services. In order to ensure the sustainability of this ecosystem, the demands on water require increased management through the introduction of carefully designed policy and regulatory measures.

104. Introducing water allocations for wetlands can be logistically simpler in a river or inland water system which is already regulated than in an unregulated river, especially when there are significant demands on the water resource for offstream utilization. In regulated flow situations, appropriate operating rules for dams and other flow control structures can be put in place and implemented by the responsible management agency. In particular, abstractions and discharges particularly can be more strictly controlled and monitored through formal authorizations and/or licences.

105. This situation represents supply-side management, whereby the impacts of people's activities and demands on a wetland ecosystem can, to a degree, be ameliorated by the technology inherent in physical structures and treatment works. However, there are significant disadvantages to this approach, since to be successful it requires well-maintained infrastructure that can provide for the necessary flow releases; capacity and skills to operate the infrastructure correctly; and sophisticated real-time hydrological monitoring networks.

106. In a situation where flows are unregulated, and in particular where real-time monitoring of abstractions and instream flows is not possible, demand-side management must be applied. Even though licensing procedures may be in place to control land-based impacts on wetlands, without the ability to make dedicated flow releases it still may be difficult to ensure that the required water quantity and water quality are made available for protection and maintenance of wetland ecosystems.

107. For demand-side management, the management emphasis must shift to managing, at their origin, the offstream demands and land-based impacts on water. The major advantage of demand-side management is that it can make more water available for allocation to wetland ecosystems through reduction of offstream demands, rather than relying on new or expanded water resource developments to provide sufficient water to meet the needs of both wetland ecosystems and offstream users.

108. Although demand-side management is becoming more important as the limits of available freshwater resources are reached in an increasing number of catchments, there often remains a need to balance the two types of measures (supply-side and demand-side). Some options are described in the following sections.

7.1 Demand-side management

109. Offstream water usage and the impacts of instream or non-consumptive water use need to be minimized, in order to ensure that wetland ecosystems are not compromised to the point where they fail or are irreversibly damaged. This can be achieved through improved local and regional planning to devote increased attention to demand management.

110. Rather than being allocated to solutions involving, for example, construction of further water control infrastructure, resources should be redirected to supporting change, for example, in agricultural practices, such as using irrigation systems requiring far less use of water (drip rather than sprinkler irrigation, for instance). Furthermore, funds should be used to strengthen the functions of ecosystems which provide goods and services for human benefit, such as the use of wetlands for water purification or flood control.

111. The conservation and management of existing freshwater ecosystems should be the priority, as the benefits provided by these are in most cases superior to those of created or restored freshwater ecosystems, as well as being far less costly [(see also further Ramsar guidance on wetland restoration in COP8 - DR16)].

112. Generally, water conservation and demand management interventions need to be made on at least three levels for an overall demand management strategy to be successful[30]:

- at catchment level, in order to achieve the most efficient allocations between and within major water user sectors;
- at sectoral level, in order to maximize the productive use of water and to minimize unproductive losses in production and/or delivery processes within each water user sector; and
- at end-user level, in order to maximize the efficiency and care with which water is used by individual consumers or end-users.

113. Actions concerning water conservation and demand management can be split into three broad approaches: catchment management, the application of technology, and the management of people. Each of these is further described below.

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[30] DWAF (2000). Water Conservation and Demand Management: Draft Strategy for the Forestry Sector. Department of Water Affairs and Forestry, Pretoria, South Africa.

Catchment management

114. It is becoming increasingly recognized that the most appropriate scale in which to apply integrated water resource management so as to ensure appropriate water allocations to wetland ecosystems is that of the catchment – often, but not always, a river basin from the source of the river to the sea. The Convention's *Guidelines on integrating wetland conservation and wise use into river basin management* (Resolution VII.18) [and *New guidelines for management planning for Ramsar sites and other wetlands* (COP8 – DR 14)] provide further information on linking wetlands and catchment management.

115. Sound catchment management procedures, which are based on an ecosystem approach and which include the wise use of wetland ecosystems within a catchment, can improve the quality of existing water resources, and can improve the assurance of flows and patterns of water availability, without necessarily requiring expensive structural or supply-side interventions (see also Case Study 9).

116. It is important to remember that water resource management at the scale of a catchment should not only address managing the wet parts of the system (rivers, lakes and other wetlands) but also needs to incorporate the appropriate management of terrestrial ecosystems, since inappropriate activities in these systems can impact on water management. For example, in South Africa, afforestation of grasslands with commercial plantations of alien woody species has been shown to reduce surface runoff significantly. These plantations have also led to a draw-down in the groundwater table, resulting in peatlands drying out and becoming vulnerable to fire and causing the failure of shallow wells used by local communities. Conversely, in Australia, where woodlands have been removed and replaced with cereal crops, the groundwater table has subsequently risen leading to salinization of soils and water in the catchment.

Case Study 9. Impacts of catchment drainage - the example of Wicken Fen

Much of the catchment of the River Ouse in eastern England was formerly fenland with seasonally inundated floodplains and permanent areas of open water reeds and raised mires. Drainage of the catchment over the past few hundred years for intensive agriculture has led to a lowering of the landscape by several metres through drying and loss of peat soils. The remaining wetlands have been left elevated above the surrounding landscape and are very vulnerable to drainage and groundwater pumping in the adjacent farmland.

Wicken Fen, a national nature reserve for over 100 years, is now some two metres above the surrounding farmland. The Fen is of high conservation value because of its unique and rich biodiversity and has been designated a Wetland of International Importance under the Ramsar Convention. In an attempt to stop drainage from the Fen into the surrounding low-lying farmland, an impermeable polythene membrane was installed along the perimeter of the Fen in the 1980s. As a mitigation measure this has been reasonably successful but, partly because of its relatively small size, the Fen remains very vulnerable to changes in rainfall, river flows, and groundwater levels.

117. At catchment level, strategic environmental assessment (SEA) approaches should be followed in determining water allocations between major water user sectors, in order to

identify the most efficient allocations of water between and within sectors, taking account of environmental, economic and social factors. Ideally, activities which reduce runoff or cause changes in hydrology, such as commercial forestry, should be considered as water uses and managed as such to ensure truly integrated catchment management.

118. For catchment management to be effective in fully integrating the conservation and wise use of wetlands and the promotion of demand management, those responsible for integrating the management of catchments and wetlands should ensure that the following actions are undertaken:

118.1 integrate wetland conservation and wise use into river basin management, utilizing the guidelines provided in the Annex to Resolution VII.18;

118.2 develop strategies to ensure that the use and management of water resources promote the protection of wetland ecosystems and their biodiversity;

118.3 strengthen the water conservation and demand management components of catchment management strategies or plans;

118.4 ensure that policy and planning recognize land-based activities, such as those which reduce streamflow or those which cause diffuse pollution on the catchment surface, as also being uses of water resources;

118.5 apply strategic environmental assessment (SEA) approaches in using environmental, economic and social criteria to determine the most efficient allocation of water between and within water user sectors in a catchment;

118.6 establish the benefits of wetlands to society by determining the economic value of wetlands, their functions and attributes, and incorporating these values into planning decisions;

118.7 promote inter-sectoral cooperation and coordination between the ministries of environment, water resources, and other interested public utilities and institutions;

118.8 identify and evaluate methods and initiatives that increase the yield of water resources without causing damage to or degradation of wetland ecosystems;

118.9 restore, where possible, ecosystems that have previously been adversely affected by inappropriate water resource management practices;

118.10 develop regulations for water use that recognize the need to ensure the protection and sustainability of wetland ecosystems; and

118.11 include experienced aquatic ecologists on the staff of water management institutions and agencies.

Technology

119. Technological interventions relate mostly to water conservation, and particularly to water savings. There are many examples of existing and new technologies which can provide

substantial water savings and contribute to the success of water demand management programmes, hence increasing the potential for making water available to maintain wetland ecosystem functions. Examples of different categories of such technologies are outlined below.

Maintenance of existing infrastructure

120. Significant water savings can often be effected in the short term, and with little additional capital cost, simply through ensuring the effective management and maintenance of existing water storage and supply infrastructure. A 1997 UNEP report[31] indicates that a decrease of 30%-40% in water consumption can be obtained by improving leak detection and maintenance and installing water meters. In urban areas, significant losses of water occur through undetected leaks, leaks which are not repaired quickly, and illegal connections to water supplies.

121. Another significant source of water loss is through evaporation from open reservoirs or open canals. Proper design of storage reservoirs can minimize evaporation losses, whilst the covering, where possible, of open water supply canals and the impervious lining of canals can also reduce water losses due to evaporation, seepage and evapotranspiration.

Water conservation practices in the domestic sector

122. At the end-user level, changes in behavioural practices can be effected through education programmes and appropriate pricing of water. There are a number of changes which can be made to domestic plumbing which, for an initial one-off capital outlay, can lead to significant and sustained reductions in water use. These include low-flush or no-flush toilets, toilet tank volume displacement devices, low-flow showerheads, faucet aerators, and pressure reduction devices.

123. Where dual water systems can be provided, then grey water (i.e. recycled wastewater such as that used for washing) rather than the incoming purified water supply can be used for watering gardens and lawns. Changes to building regulations and their equivalents can help to ensure that the best available water-efficient technology is used in all new buildings.

Water conservation practices in the agricultural sector

124. Irrigation agriculture is one of the largest water use sectors in the world, using up to two-thirds of all freshwater removed from rivers, streams, lakes and aquifers[32]. In many countries, irrigation is still carried out by age-old gravity-fed techniques, channeling water through furrows into flood basins. Lining of furrows, canals and reservoirs with clay or plastic, and proper scheduling of irrigation according to soil moisture levels, can still lead to significant savings even with these relatively low-technology irrigation methods.

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[31] UNEP (1997). Source book of alternative technologies for freshwater augmentation in Latin America and the Caribbean. United Nations Environment Programme International Environmental Technology Centre. www.oas.org/usde/publication/unit/oea59e/begin.htm

[32] Postel S (1997). The Last Oasis – Facing Water Scarcity. Worldwatch Environmental Alert Series, Norton, New York.

125. Elsewhere, changing from high-volume sprinkler or overhead irrigation to low-volume techniques such as drip or microjet irrigation requires high initial capital outlay but yields substantial water savings and improved crop yields. With careful management and proper treatment, recycled wastewater can be used to irrigate certain crops.

126. In arid regions, planting of drought-tolerant crops or crops suited to the seasonal rainfall regime reduces reliance on irrigation water and also reduces crop losses in dry years. Seasonal rainfall forecasting techniques are now being developed to allow farmers to manage their crop selection according to projected seasonal rainfall[28].

Water conservation practices in the industrial sector

127. Industry accounts for nearly a quarter of the world's water use. In the industrial sector, water is generally used either in production or in cooling processes. Experience has shown that a strong policy environment is usually most effective in promoting water savings in industry: appropriate tariff policies and load-based charges or restrictions on waste discharges can encourage significant water savings. Options for water saving in industry include the introduction of closed-loop technologies and the use of recycled water in both production and cooling.

Alternative sources of water

128. In water-scarce areas, where communities may not be located near a water source or near supply infrastructure, there are a number of alternative solutions which can be used to augment freshwater supplies. These include:

128.1 rainwater harvesting, where each household collects roof water and runoff water in drums, tanks or reservoirs;

128.2 fog harvesting, especially in arid western boundary current regions such as the west coasts of Namibia and Chile, which can yield up to 3 litres of water per day per square metre of collecting mesh;

128.3 aquifer recharge, which recharges groundwater supplies, can improve water quality and reduce evaporation losses from surface storage;

128.4 desalination of seawater for coastal towns and cities, still a relatively expensive technology (costs range from US$1 to US$4.30 per cubic metre), but which is increasingly used to supplement public water supplies; and

128.5 "Virtual" water, whereby water-scarce countries import water-hungry products from areas where water is plentiful rather than producing these products themselves, although this requires regional economic and political stability to be successful in the long term.

129. To minimize water use through the application of technologies for water conservation and demand management, the following actions should be undertaken:

129.1 ensure proper maintenance of existing water storage and supply infrastructure;

129.2 provide incentives for installation of water savings devices in households and industry;

129.3 consider alternative sources of water to augment existing freshwater supplies before developing new freshwater sources;

129.4 provide incentives and technical support for farmers to implement irrigation scheduling and water-efficient irrigation practices; and

129.5 in water-scarce areas, encourage the production of goods (including crops) which do not have high water needs in their production processes.

Increasing stakeholder awareness of sustainable water resource management

130. The success of putting in place measures to reduce or minimize water use, and to allocate water to wetland ecosystems, will depend on the understanding and support of those people who will be affected by any new management intervention.

131. In many situations, and especially where water resources are already heavily utilized, there may be resistance from people who are reluctant to change the ways in which they use water in order to make more water available or to reserve water for protection of wetland ecosystems. Gaining people's acceptance and support for change is dependent upon their awareness of the issues involved, and of what costs or benefits exist for them. Therefore allocation of water and its management for maintaining ecosystems relies upon comprehensive education programmes; on the correct incentives being available; on the perception that equitable benefits are being shared; and on achieving a common understanding of what the ecosystems provide, and hence the state in which they should be maintained.

132. To increase public and stakeholder awareness through the promotion of water conservation and demand management, the following actions should be undertaken:

132.1 follow an integrated least-cost planning approach (Integrated Resource Planning) in developing linked strategies for water resource management and water service delivery;

132.2 create a culture of water demand management amongst all consumers and water users through national education and awareness programmes;

132.3 ensure the implementation of water demand management principles within all water management and water services institutions;

132.4 ensure that tariffs implemented by water institutions promote water demand management and water conservation;

132.5 promote the development of new technologies that enhance water savings and demand management;

132.6 develop policies for water institutions that will allow the funding of water demand management initiatives;

132.7 introduce regulations that limit the wastage and inefficient use of water in all sectors;

132.8 develop incentives and rewards for water conservation and demand management initiatives; and

132.9 make reporting on water conservation and demand management an integral part of environmental or general business reporting for all public sector and parastatal institutions and for bulk water users in the private sector.

7.2 Supply-side management

133. Supply-side management refers to mitigation of the impacts of water use on wetland ecosystems through interventions which are targeted at the supply side, i.e., between the source of impact and the wetland ecosystem itself, rather than attempting to change the water use itself or the impacts of that use. In almost all cases, supply-side interventions are expensive and technically demanding, but do have their place in managing water allocations for wetland ecosystems.

134. In a river basin which is already regulated, dams and flow control structures may be in place, and offstream water uses may have become well established over the years, but without making allowance for the water required for wetland ecosystems. In such cases, by modifying current release patterns and levels of assurance it may be possible to make releases from dams specifically for ecological purposes while still meeting the demands of offstream users. In some rare cases, a dam might even be decommissioned, especially if it is nearing the end of its lifetime and its storage capacity is no longer needed. This is already happening to some older dams in the United States of America.

135. Frequently, however, existing dams remain necessary, but may not have been designed to allow release of larger flows such as those required for scouring floods, or do not have variable-level outlets to prevent release of anoxic bottom water. In cases where the physical operating constraints do not allow the full implementation of the required flow regime that has been determined for a wetland ecosystem, then a flow management plan can be put in place. A flow management plan represents the best that can be done towards providing more natural flows to restore some (but not all) wetland ecosystem functions, within the constraints of the existing infrastructure.

136. If offstream demands cannot be reduced so as to make water available for wetland ecosystems, then inter-basin transfers can be considered, where water is imported from another catchment to meet the combined needs of the water users and the wetland ecosystem in the recipient catchment. However, there are significant disadvantages to this strategy, including the potential negative impacts on wetland ecosystems in the donor catchment through loss of flows, and the potential contamination of the recipient catchment with water of a different quality, foreign genetic material, and/or invasive alien species.

137. In cases where water quality has become degraded, it is sometimes possible to divert streamflow or abstract groundwater for treatment and then return the treated water to its original water body. For example, in the restoration of the Nardermeer and Nieuwkoopse

Plassen wetlands in the Netherlands, inflowing water is subjected to pre-treatment to remove phosphate, and wetland sediments are being dredged and treated to remove contaminants which have been deposited there over the years due to polluted inflow. However, this intensive approach is only usually practical with small streams and low volumes of water.

138. Finally, another supply-side management option for a degraded water supply is to import or transfer better quality water to be blended with water of poor quality. This option is sometimes used in the management of salinisation of water resources caused, for example, by irrigation return flows. However, the use of clean water to dilute polluted water is not consistent with the principles of wise use, and should be considered only if a proper valuation process indicates this to be the most cost-effective solution to a pollution problem.